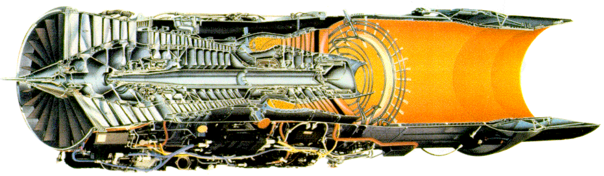
Reliability Centered Maintenance (RCM) on USAF Gas Turbine Engines

NDIA Conference, Sept. 16th 1998



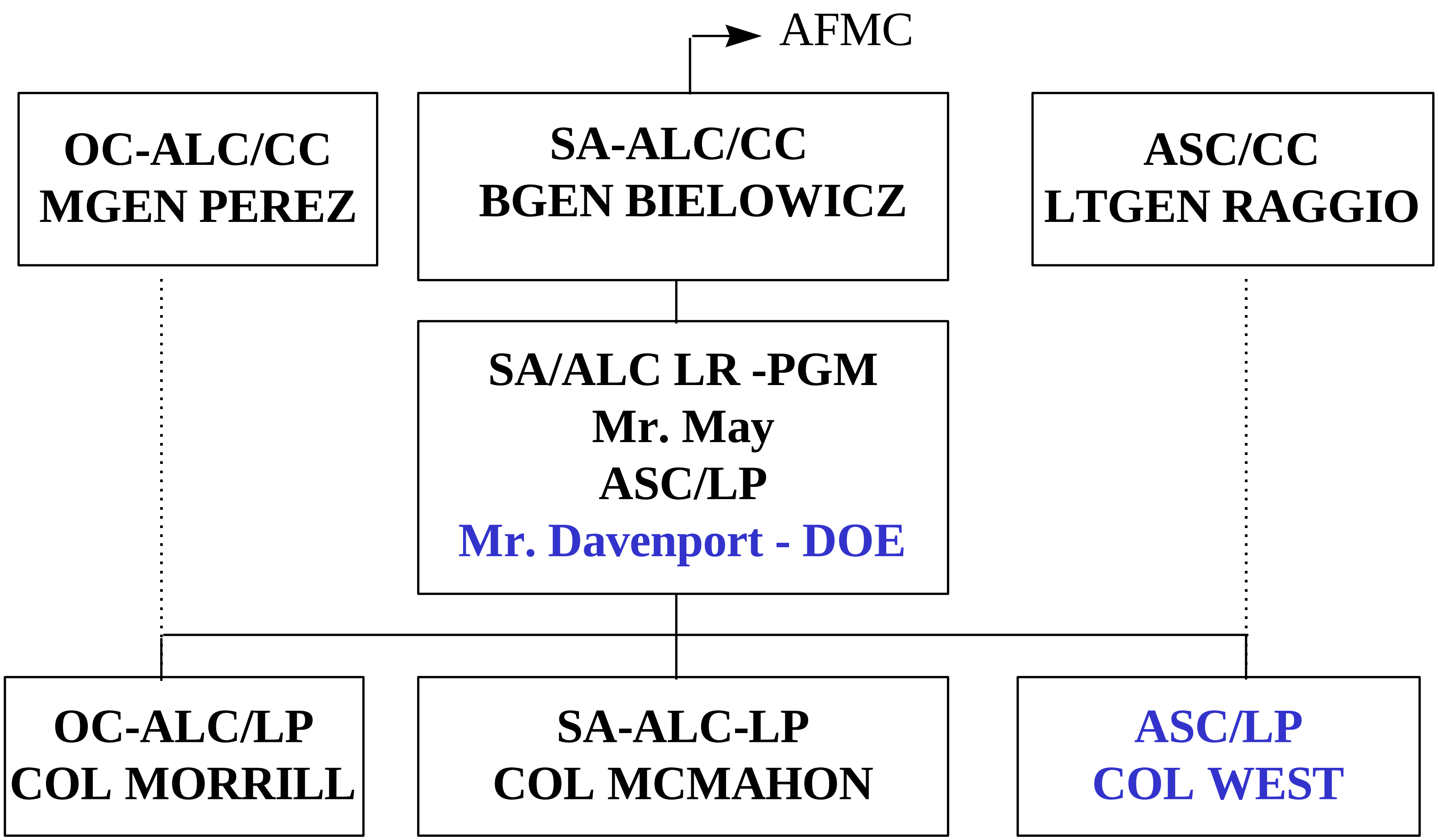
R. L. Scott / ASC/ LP

TOPICS

- **Introduction**
- **What is RCM / RCM History**
- **RCM vs OCM in Engine Maintenance Planning**
- **F100-PW-220/E RCM Demonstration at Luke AFB**

INTRODUCTION

USAF Propulsion Product Group- Organization



INTRODUCTION

- ***DSO MISSION***
- **DEVELOP, ACQUIRE, FIELD, AND SUSTAIN AFFORDABLE AND SUPERIOR ENGINES IN SUPPORT OF OUR CUSTOMERS REQUIREMENTS**
- ***DSO GOAL***
- **BECOME THE DEPARTMENT OF DEFENSE SUPPLIER OF CHOICE FOR THE WORLD’S BEST PROPULSION SYSTEMS**

INTRODUCTION

Current USAF Propulsion DSO Programs

Engine	Aircraft	ASC/LP IPT
F119-PW-100	F-22	LPR
F100-PW-229	F-15/F-16	LPP
F100-PW-129	F-16	LPP*
F118-GE-100	B-2	LPB
F118-GE-101	U-2	LPB
F117-PW-100	C-17	LPC
FMS Engines	F-15/F-16	LPX
JSF		LPD

* Transferred to OC-ALC in June 98

WHAT IS RCM ?

DEFINITION

"A disciplined logic or methodology used to identify preventative maintenance tasks to realize the inherent reliability of equipment at the least expenditure of resources."

Or...

"Fix what is broke and what may break within the next service interval."

Or...

"Preventative Maintenance"

HISTORY OF RCM

- **Original Maintenance Philosophy of Jet Engines - Max Overhaul Time - MOT**
  - Based on a philosophy that every mechanical system has a right MOT
  - Initial MOT limits were not analytically based
  - Significant efforts applied to growing specified MOT
    - Used sampling of reliability data and analytical teardown of extended time engines
  - Ultimate Conclusion
    - Most items had no right overhaul time
    - MOT gave up component life
    - Statistical analysis showed no change in safety or reliability when MOT limits changed

HISTORY OF RCM

- **MOT Gave Way to an "On Condition" Maintenance Philosophy**
  - Physically inspect for failures at predefined intervals
  - All parts reach more of their inherent reliability
- **"On Condition" Could Not Predict Many Hidden or Complex Failure Modes**
- **Led to Unanticipated Consequences and Unanticipated Equipment Down Time**

HISTORY OF RCM

- **Reliability Centered Maintenance**
  - Born out of joint FAA and Airline Association Maintenance Steering Group (MSG) to develop initial maintenance program for the 747 aricraft
  - Put forth a series of logic paths that systematically reviewed the aircraft's design so that the best maintenance process could be used for each component or system
  - Sorted out potential maintenance tasks and then evaluated them to determine which must be done for safety, hidden failures or economic benefit
  - Also combined scheduled tasks with condition monitoring and "on condition" maintenance

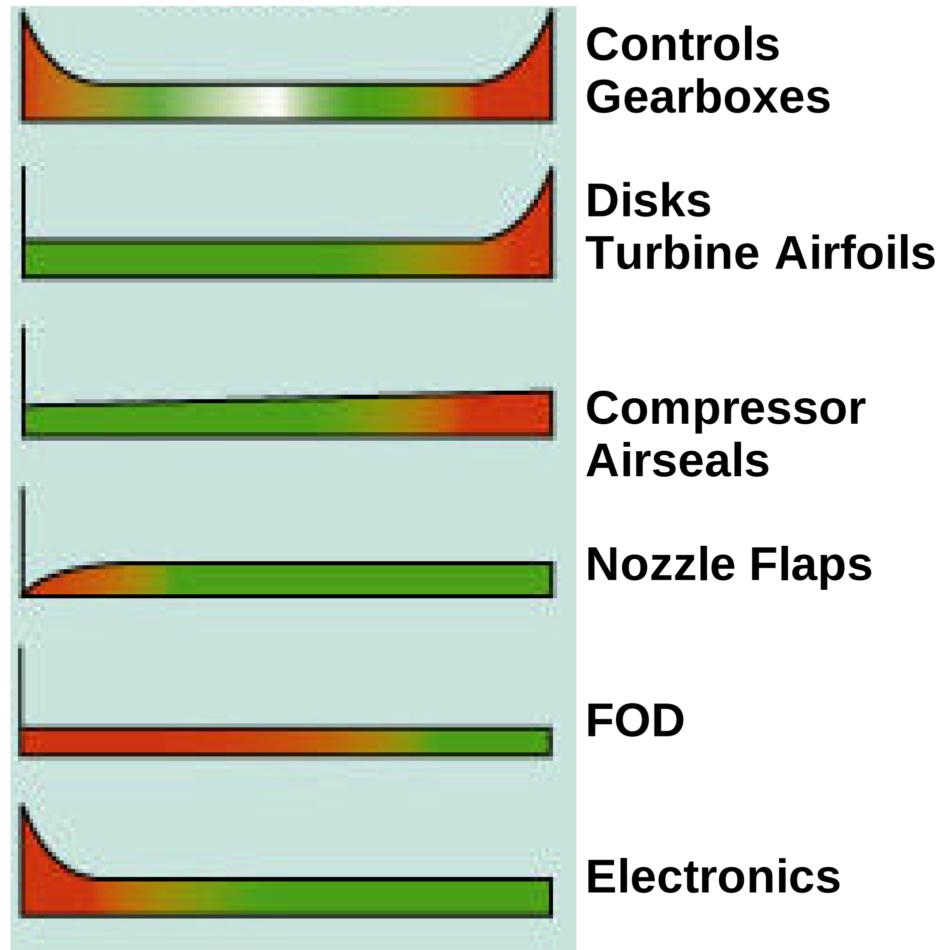
HISTORY OF RCM

- **MSG 2 - Refined the RCM Process**
  - Applied to the initial maintenance plans of the DC10 and L1011
- **MSG 3 - Refined the Process Further**
  - Strengthened the process (feed back loop) for constantly reevaluating maintenance programs
    - RCMA - Reliability Centered Maintenance Analysis
    - Needed as experience was gained and as the system ages
  - Application to pre-existing systems

OCM VERSES RCM in ENGINE MAINTENANCE PLANNING

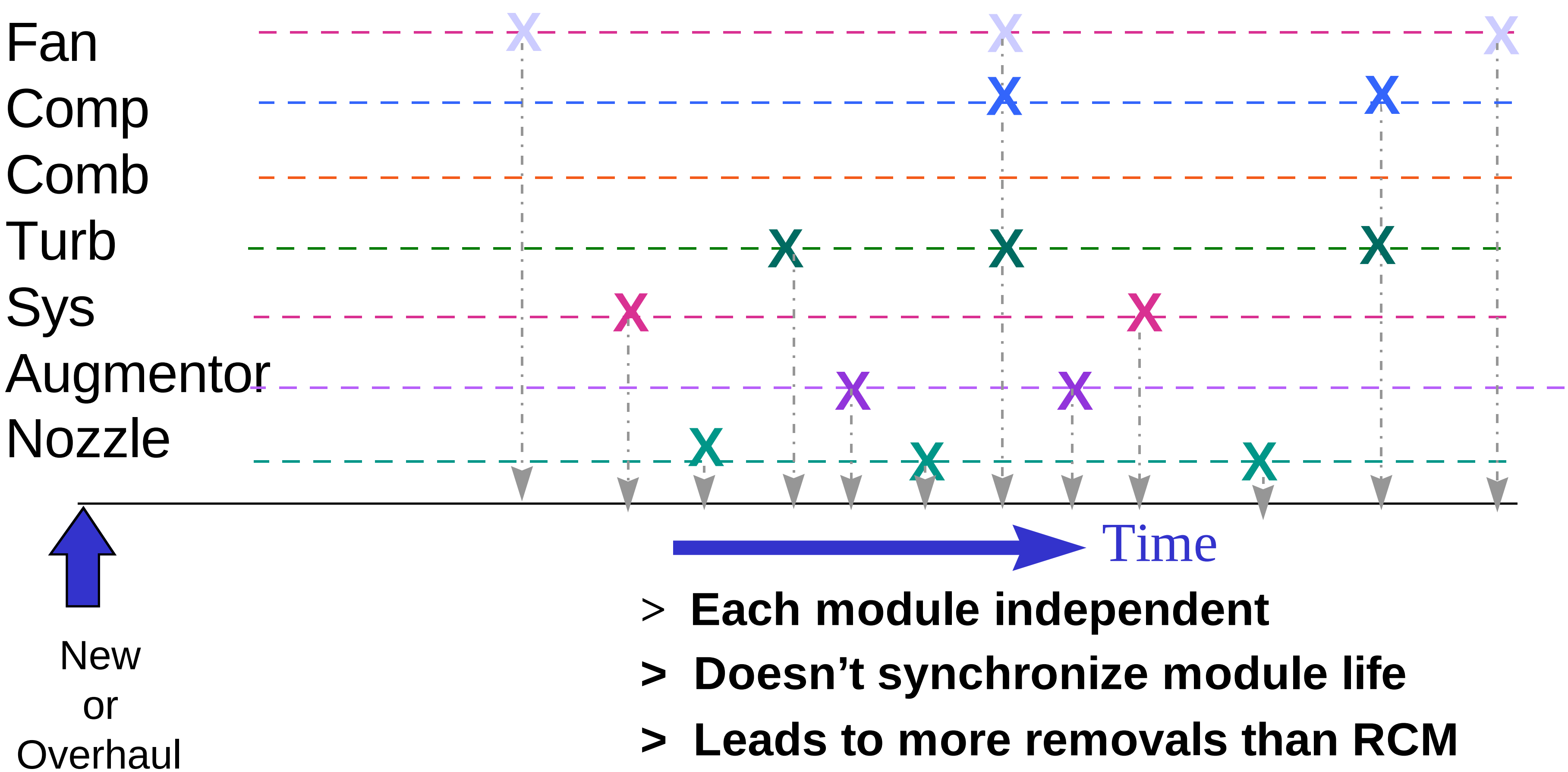
- **“Routine maintenance is about avoiding, reducing or eliminating the consequences of failures”**
    - RCM gives preference to <u>planned</u> maintenance
    - OCM gives preference to <u>unplanned</u> maintenance
- **“It is nearly always more cost-effective to try to improve the performance of an unreliable asset by improving the way it is operated and maintained...”**
- **RCM is USAF Policy**

Patterns of Equipment Failure



OCM VERSES RCM in ENGINE MAINTENANCE PLANNING

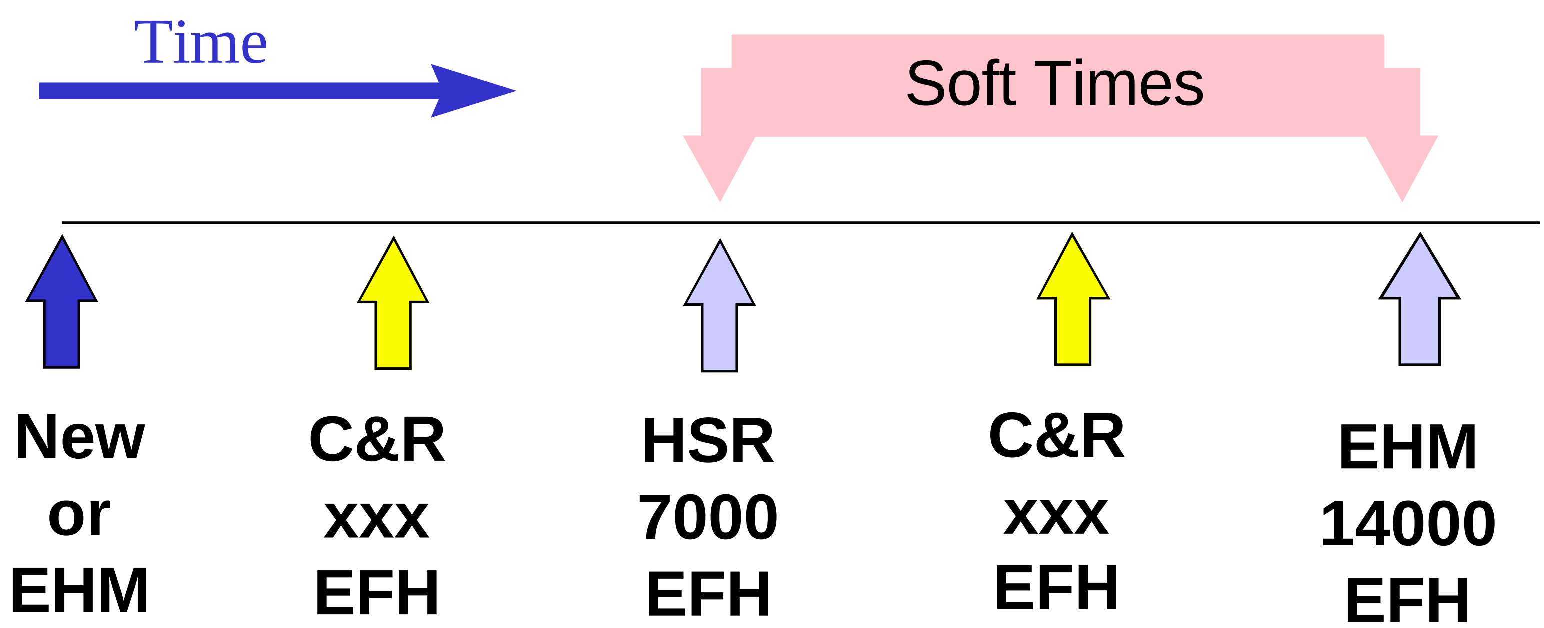
TYPICAL USAF PRACTICE



- > **Each module independent**
- **> Doesn't synchronize module life**
- **> Leads to more removals than RCM**

RCM in COMMERCIAL PRACTICE

RCM: Achieve inherent reliability via planned maintenance

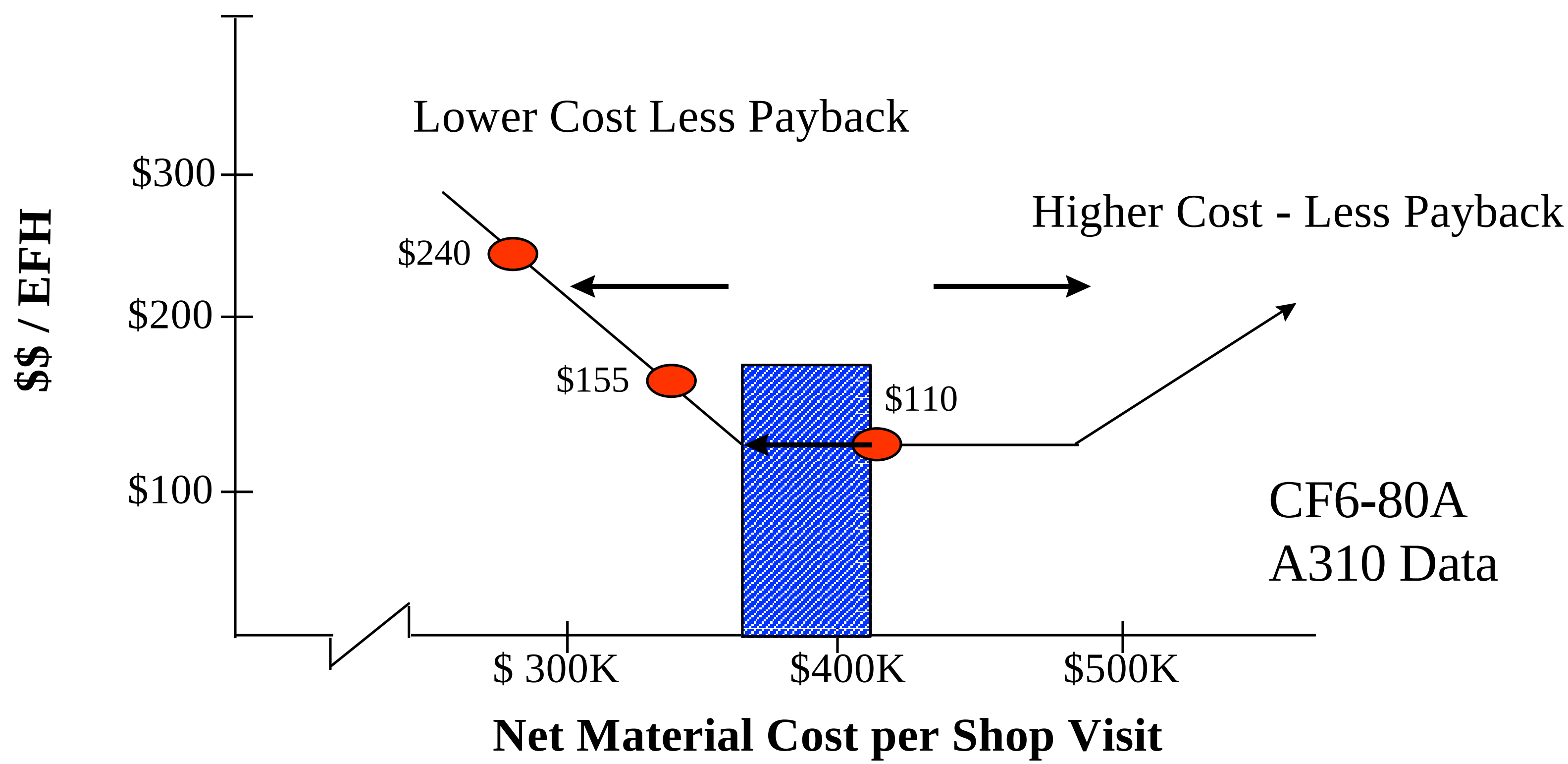


C&R = Check & Repair -- Fix only what drove off wing//Update to next interval
HSR= Hot Section Repair -- Reblade HPT, insp. & repair as necessary on other modules
EHM=Engine Heavy Maintenance -- Restore life for all modules

Maintenance Planning by IPT: Individual Engine Work Scoping

RCM in COMMERCIAL PRACTICE

Work Scope - Value Relationship



30% Increase in Material Cost/Shop Visit =55% Lower Cost/EFH

F100-PW-220/E RCM DEMONSTRATION

F100 Fighter Engine Family Overview

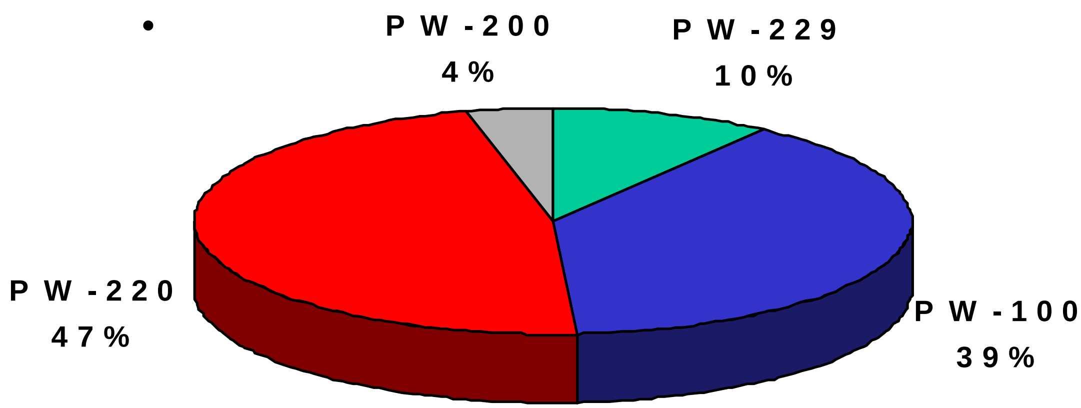
Engine Model	Thrust-Lbs Class	Engine Quantities	Engine Flt. Hours	Aircraft F-15	Aircraft F-16
F100-PW-100	24,000	1,629	7,241,100	858	
F100-PW-200	24,000	807	3,949,500		658
F100-PW-220/E	*24,000*	*2,257*	*2,488,100*	*307*	*807*
F100-PW-229	29,000	392	318,100	113	109
Total		4,985	13,996,800	1,278	1,574

Note: Worldwide except Japan and engines/aircraft in storage at Davis-Monthan AFB

F100-PW-220/E RCM DEMONSTRATION

USAF F100 Fleet

3000 Active Engines - In Service Since 1974



- F100-PW-100 (1974) powers F-15A/B/C/D
- F100-PW-200 (1978) powers F-16A/B
- **F100-PW-220 (1987) powers F-16A/B/C/D and F-15B/C/D/E**
- F100-PW-229 (1991) powers F-16C/D and F-15E

Luke AFB 56th Fighter Wing R & M Data - Jan 97- May 98

	Luke	Remaining Fleet (11 Bases)
Engines	211 (26%)	598 (74%)
EFH/month	4161 (36%)	7357 (64%)
UERs	201 (31%)	439 (69%)
SERs	308 (44%)	396 (56%)
UER Rate	3.15	2.92
SER Rate	4.77	2.91
SVR	7.92	5.82
# Shp Vsts/Mo	30	77
TAC/EFH	2.61	2.16
ABLites/EFH	4.22	3.90

F100-PW-220/E RCM DEMONSTRATION

220/E DEMO IPT

PPGM / PPG Technical Director

RCM IPT Leaders
SAALC/LPF & ASC/LPP

RCM Team Members:
Pratt & Whitney, USAF/ASC, /SA-ALC, /AETC & 56th FW at Luke, Logtec

Control & Metric Tracking Team
- Design of Test
- ELMP
- Maintenance Management Plan
- Metrics (SER, UER, SVR, etc)
- Operational data analysis
- Engine & module tracking
- Mission data
- RCM tracking procedures & plan

Cost Benefits & Hwd Team
- Parts Analysis
- Hardware Availability
- Build Standard
- Cost Accounting
- Cost Benefit Analysis
-

Engineering Team
- Memorandum of Agreement
- Maintenance Instructions
- Performance Trending
- Levels of inspection & repair
- Module & part matching
- Repair expansion
- Life limit extensions
- Special equipment

F100-PW-220/E Demonstration Plan - Overview

- Demo Pilot - 1 Oct. 98 - 30 Sept. 99
- Where - 56th FW (AETC) at Luke with qty. 187 F16C/D220/220E

Approach

- <u>Phase 1</u> (ongoing) - Establish module/engine build policy
  - Identify SVR drivers, determine available fixes, conduct cost/benefits analysis, develop workscope matrix for I & D level, optimize module matching at Luke.
- <u>Phase 2</u> (ongoing) - Implement build policies at SA-ALC and Luke
  - Revise I & D level T.O.s as needed
  - Provide any enhanced I level capability
- <u>Phase 3</u> - Monitor, collect and analyze reliability and cost data
  - Final report by 1 November 99
  –

F100-PW-220/E RCM DEMONSTRATION

- Demo Objectives -

Today (USAF fleet)

SER/1000	**3.06**	
UER/1000	**3.07**	
SVR/1000	**6.13**	
$/EFH	**> $510**	
MTBR	**< 200 EFH**	
Depot Interval **(**avg TACS/ unscheduled JEIM Removal**)**	**3K/4K Fan** **4K Core** **3.5K LPT** **2K Aug** **1800 MOH GB**	**(1820)** **(1850)** **(1520)** **(1500)** **(1250)**

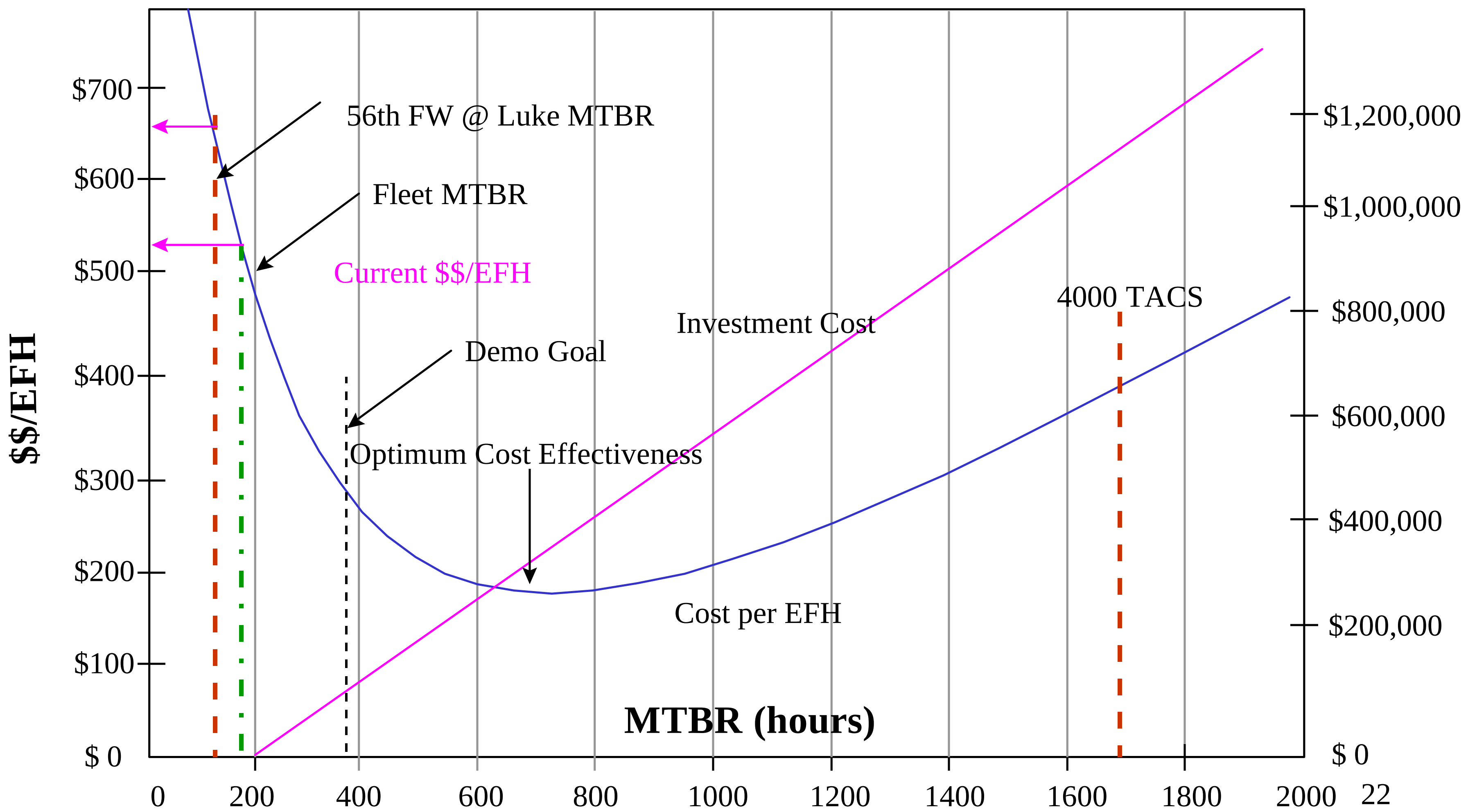
Potential

SER/1000	**2.2**
UER/1000	**1.1**
SVR/1000	**3.3**
$/EFH	**$280**
MTBR	**> 500 EFH**
Depot Interval (TACS)	**4K Fan** **4K Core** **4K Aug** **3000 MOH GB**

F100-PW-220/E RCM DEMONSTRATION

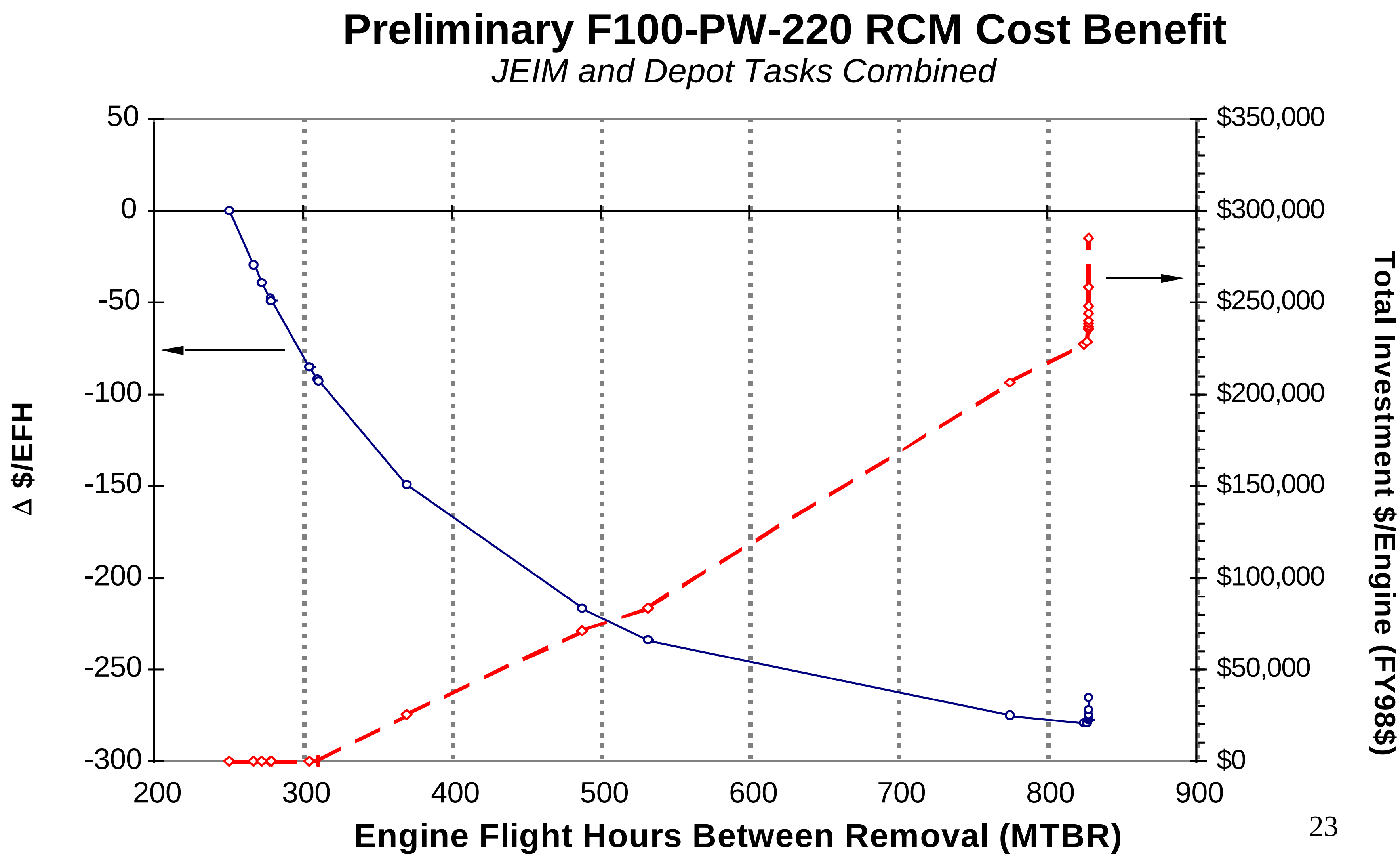
Maintenance Cost Theory

Projected Operational Costs Vs Time Between Engine Removal



F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO



Depot Build Standards for Luke AFB RCM Demo

"A" Standard - REP FAN / CORE / LPT / Augmentor

- Delta cost $193K/Engine

"B" Standard - REP FAN / CORE / LPT

- Delta cost - $ 0**

"C" Standard - REP FAN / 220E CORE / LPT

"D" Standard - REP FAN or CORE or LPT

"E" (lead) Standard - All other configurations

** Cost of improvements is negotiated in current overhaul price

F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO

Build Standard Recommendations

Fan Module
- REP (4000 Cyc Conf)
  - 3rd Disk/Blades
- Sq Drive CIVV System

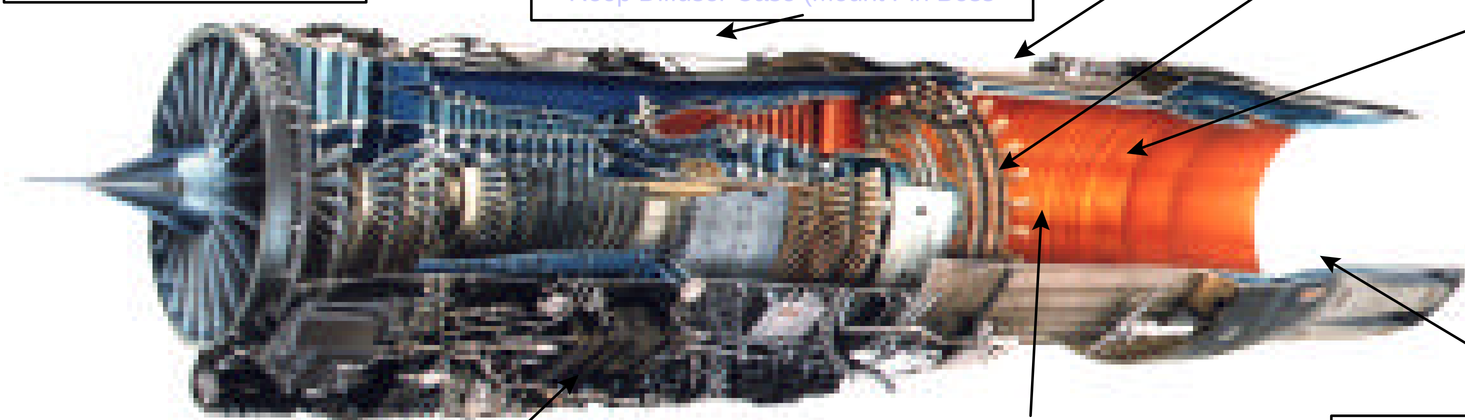
TCTO exists
ReOp/
MOH extension
Funding Required

High Pressure Compressor
- -220 Configuration (employs MOP)
  - ID Seals/Honeycomb
  - Blade Length
  - 220 Aero
- Zero Time 4th Blades
- 2 Degree RCVV DEEC Logic
- RCVV Bushings
- 13th Stage Bleed Rods
- Ni Braze Fuel Nozzles
- Fuel Manifold 11J Clamps
- Reop Diffuser Case (Mount Pin Boss

Externals & Controls
- Hi Temp CENC
- Anti-ice Valve Kit
- 2.5.3/5.3.0 DEEC
- 2.4.0 EDU
- FTIT Probe Check
- Upgrade ENPT
- Nomex Cables
- PDC Stacked Orifice

High Pressure Turbine
- MOP (new/ 2nd Stg Blades
- Aerex 350 Pins and Collars
- 2nd Stg BladePi Tape Measurement
- HPT Assy/Disassy Tooling for JEIM

#5 Bearing Compartment
- Redesigned Tubes
- Anti-siphon hardware



Lube and Gearbox
- 1800 MOT Gearbox (extend to 2000 MOT)
- Improved Oil Servicing Procedures
- Improved Lube System

Low Pressure Turbine
- REP Turbine (4000 Cyc Config)
  - 3rd Disk/Blades
  - 4th Disk/Blades
  - 3rd Vanes
  - 3rd BOAS
  - 2nd BOAS Support
  - Rim Seal

4000 Cyc Augmentor Module
- 12 new parts
- 24 re-operated parts
- Actuator Gear & Ball Screw
- Clean Spray Rings
- Self Cleaning Spray Rings (1,2, 4)
- Cut Back Fingerseals

F100-PW-220/E RCM DEMONSTRATION

Propulsion DSO

Master Schedule